# Vehicle Health Maintenance and Analysis Using Advanced Statistical Methods and Adaptive Techniques

## Project Number: 96-10


## Investigator: A.R. Kelley/EB23


### Purpose

The Center Director's Discretionary Fund proposal, Vehicle Health Maintenance and Analysis Using Advanced Statistical Methods and Adaptive Techniques, was funded in October 1995 for 2 years and extended 1 year at no additional cost. The primary objective is to apply statistical methods, genetic algorithms, neural networks, expert systems, and fuzzy logic to vehicle health monitoring systems or other MSFC systems requiring problem resolution. These methods successfully solve several kinds of problems.

### Background

After the application of artificial intelligence (AI) techniques to several MSFC problems, the Space Shuttle main engine (SSME) was chosen for detailed analysis. The SSME is ideal for developing a combined architecture for the fuzzy, neural, expert, and statistical systems due to the complexity, large historical database, and models of internal processes.

The current SSME monitoring system uses hardware redlines. For example, if a pressure or temperature measurement exceeds a pre-determined hardware failure limit, then the engine is shut off. Both single and redundant sensors are used for these redlines, but there are few algorithms using different types of sensors, such as combining both a temperature and a pressure for one redline.

Currently being developed are some model-based techniques for monitoring engines, which do combine different sensor readings. These model-based techniques detect failures by comparing actual sensor values to the predicted model values. This will greatly enhance the SSME health monitoring, but has some drawbacks. First, the model must be very good, which usually makes it very expensive and requires substantial development time. Second, modifying or changing the engine hardware may require model modification or new model generation.

### Approach

The purchase of several low-cost software tools enables an easy comparison or evaluation on neural networks, fuzzy logic, expert systems, statistical methods, or any combination of these techniques when applied to a particular problem. This comparison allows exploration of the strengths and weaknesses of each system or combination, e.g., the neural and expert system combination versus a single fuzzy system. Combining these techniques with redline methods should lead to an improved vehicle health management system. The ultimate goal is to create a technology applications handbook using the knowledge gained from these comparisons.

### Accomplishments

There were several accomplishments in the last year. First, an expert system was developed and is currently monitoring Stennis ground tests for the block II engine tests. The expert system may possibly be incorporated in the engine controller for real-time vehicle health monitoring if the test phase results are good. Each detected blade failure could save a turbopump ($2–4 million) or an engine ($40–60 million). The same analysis techniques should be applicable to anomaly detection in other types of turbines, engines, and industrial machinery. Second, a patent application on this expert system was initiated and should be filed within the coming year.

Finally, there were several publications based on this research. The SSME expert system was published in the MSFC Research and Technology report and two NASA Tech Brief articles were accepted and should be published within a few months.

## Planned Future Work

Future work in this research will concentrate on the following areas:

- The use of artificial intelligence to create sensor redundancy and sensor validation algorithms;
- To develop an adaptive health monitoring system that responds to small hardware changes;
- To create a real-time diagnostic system by chaining several small expert, fuzzy, neural, and statistical systems together;
- To apply these technologies to the vehicle management system on the Reusable Launch Vehicle;
- To support and update the turbine blade failure detection algorithm; and
- To complete the patent application package.

## Publication and Patent Applications

- Published in the 1996 Research and Technology Report
- Submitted two NASA Tech Brief articles
- Initiated patent application

## Funding Summary ($k)

| | FY96 | FY97 | FY98 | Total |
|---|---|---|---|---|
| Authorized amount: | 19 | 3 | 2 | 21 |
| Obligated to date: | 17.3 | 1.8 | 0 | 19.1 |

## Status of Investigation

Project approved—October 1995 (FY96)

Project estimated completion—September 1998 (FY98)

# Development of Advanced Brazing Techniques

## Project Number: 96-13

## Investigator: W.B. McPherson/EH23

### Purpose

The purpose of this effort is to develop brazing techniques for assembling propulsion system components. Fabrication will be simpler, more reliable and faster to produce, all at a lower cost than present assemblies. Ultimately, this work will lead to fabrication of a complete combustion chamber.

### Background

Fabrication of the SSME combustion chamber has always been very time consuming and costly. With the advance of casting technology, a combustion chamber jacket can now be cast as a single piece. The challenge is to join a liner to the cast jacket.

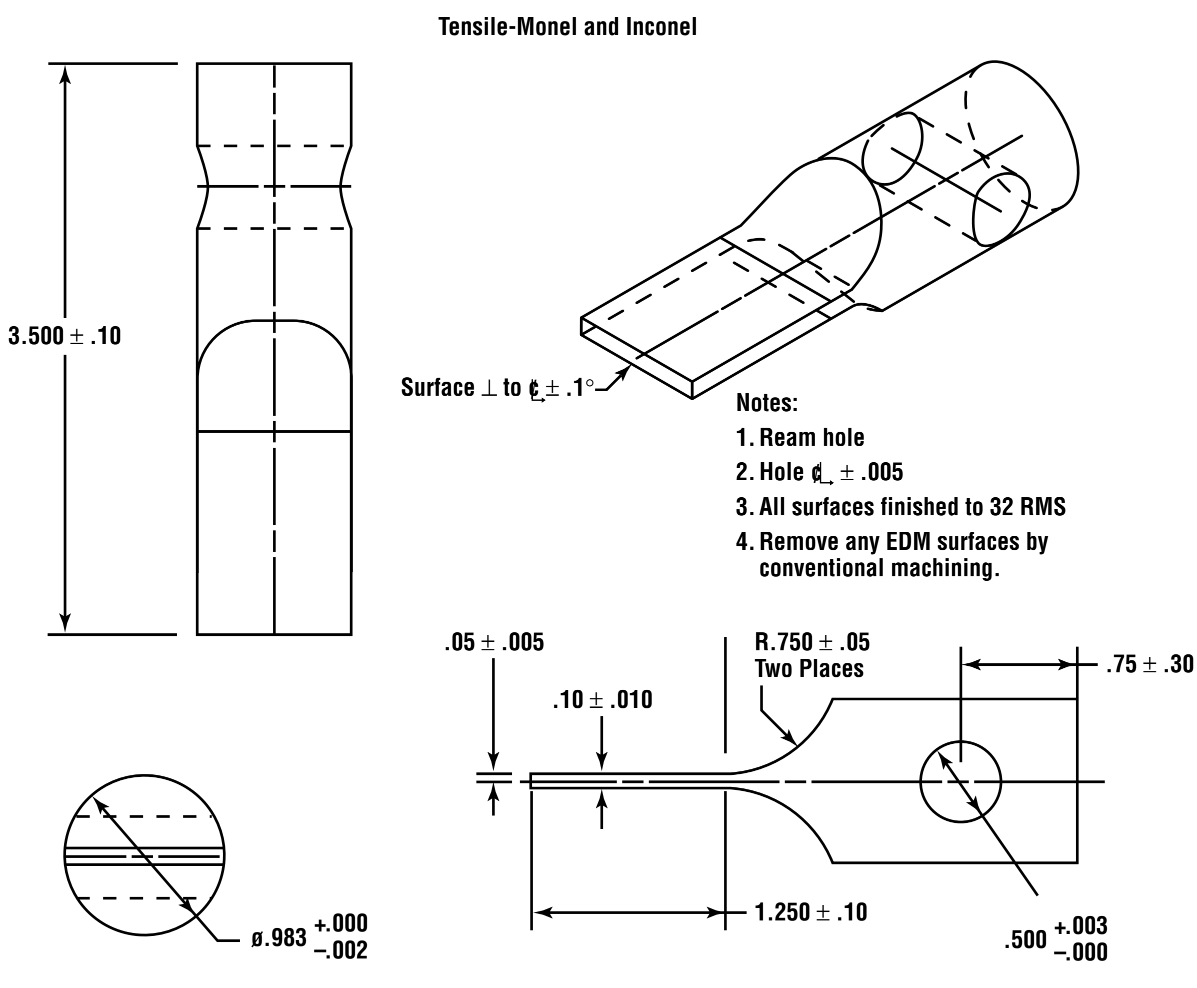


FIGURE 12.—Half tensile specimen for evaluating braze alloy and joint metal.

## Approach

To establish a fabrication procedure, clean nickel plating (required for precipitation hardened alloys), and evaluate braze alloys to select the best bond process. With a successful braze joint, a liner will be brazed into a cast jacket.

## Accomplishments

- Attended a course entitled “Modern Furnace Brazing (not funded by CDDF)
- Procured cast NASA 23 plates, 1×15×20 cm (.35×6×8 inches)

## Planned Future Work

We plan to machine test specimens; evaluate the braze process; develop casting—channel contour and subscale configuration; and fabricate a subscale combustion chamber.

## Funding Summary ($k)

| | FY96 | FY97 | FY98 |
|---|---|---|---|
| Authorized: | 75 | 75 | 0 |
| Obligated: | 75 | 75 | 0 |

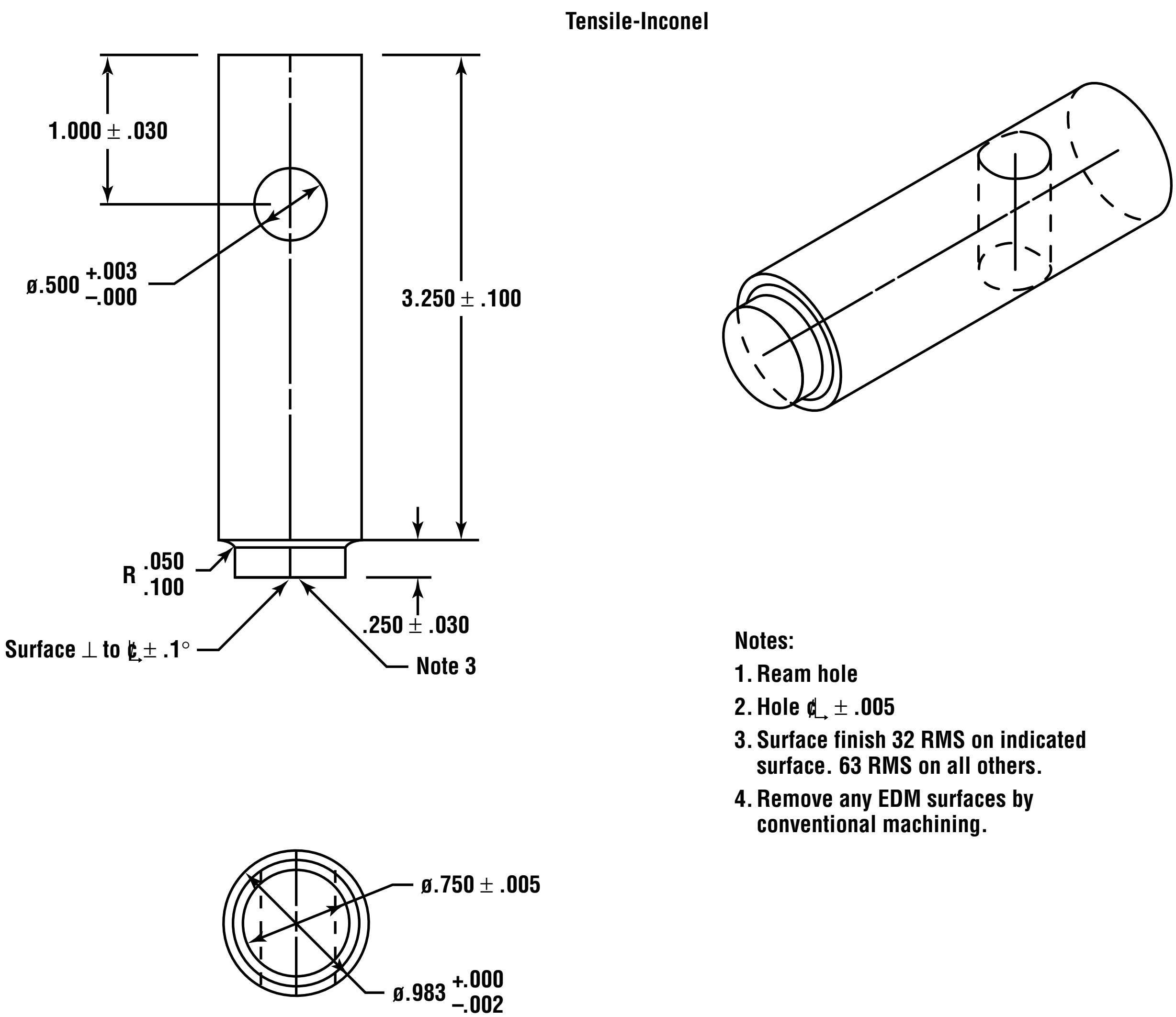


FIGURE 13.—Half tensile specimen.

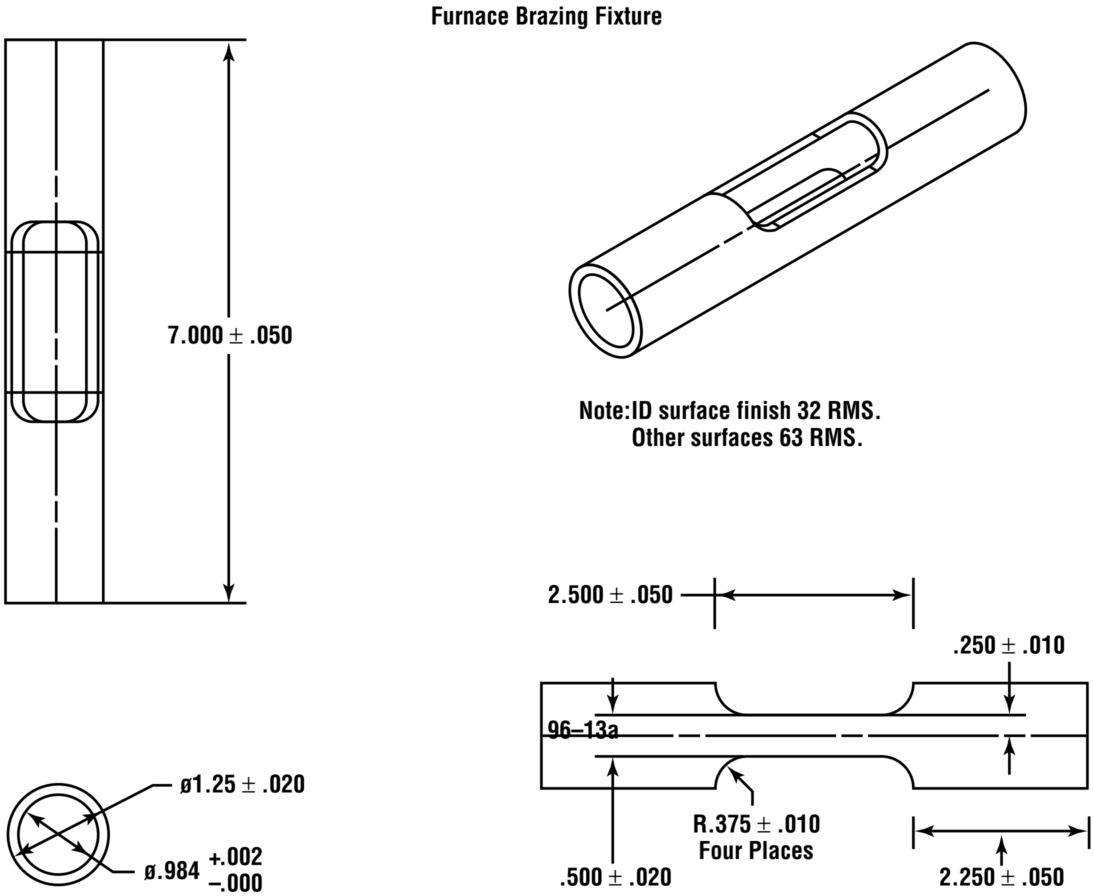


FIGURE 14.—Furnace brazing fixture for tensile specimen.

## Manpower Summary

| | FY96 | FY97 |
|---|---|---|
| Predicted: | 0.5 man-year (2 engineers) | 0.7 man-year (1 engineer) |
| Actual: | 0.05 man-year (1 engineer) | 0.05 man-year (1 engineer) |

| | FY98 |
|---|---|
| Predicted: | 1.5 man-year (1 engineer and 1 contractor—IITRI) |

## Status of Investigation

We will continue through FY98 with our remaining FY97 funds. Our estimated completion date is September 30, 1998.